Research on benefit and optimum development of residents ' heating projects based on different ways

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Abstract: At present, the relevant experts pointed out that the emergence of China's foggy weather is the coal-dominated irrational energy consumption patterns and energy structural contradictions in the long-term accumulation of concentrated exposure. The air pollution caused by coal-fired heating in the northern cities is again attracting attention. As a new type of heating mode, electric heating enters people's view. In order to make the public understand the characteristics of electric heating, this paper firstly analyzes the technical scheme of electric heating, then takes the project of North China as an example to carry on the economic benefit analysis research,and according to the appraisal result gives the government subsidy electricity price proposal, has the important practical reference significance to the electric heating implementation promotion

1.Introduction

At present, the efficiency of the coal-fired boilers used by residents is usually not high, decentralized coal-fired boiler heating also causes a low utilization of fuel.Therefore, it is of great significance to use electric heating instead of coal-fired boilers to increase the proportion of energy consumption and to change the mode of energy consumption and improve the efficiency of energy utilization.

The implementation of residential electric heating will concentrate coal on large-scale combustion to generate electeicity, and then use electric energy to drive heating equipment, the impact on the atmospheric environment is far lower than the direct emission of decentralized coal-fired boiler.

This paper takes a residential district project in Yanbian area as an example, and analyzes the economic angle of different heating modes from the aspects of investment cost, operating cost and annual cost, making a comprehensive quantitative evaluation on the benefits of electric heating.

2.Research trends of Electric heating

Many scholars have probed into the necessity and application technology of electric heating, and [1] have pointed out the necessity of implementing electric heating from the angle of improving energy efficiency and reducing environmental impact. [2] regarded electric heating as one of the important means of "reducing the burden" of environmental pollution. [3] have studied the mainstream form and application of electric heating at present, and pointed out that the electric heating has been widely popularized. [4]proposed a multilayer phase change heat storage System,conducting performance simulation of the thermal storage unit for the system by establishing the mathematical model,it is found that the system has great application value in electric heating at home.[5]had proposed the concept of geothermal energy as the low temperature heat source of ground source heat pump system , and [6-7] have carried out a lot of basic theoretical research on ground source heat pump.

3.Current status of residential electric heating and analysis of electric heating technology

3.1 Current status of residential electric heating

At present, 80% of China's energy consumption is direct combustion of raw coal, resulting in environmental pollution problems, has affected the sustainable development of national economy and the people's physical health. 70% and 90% of China's emissions of soot and sulfur dioxide are produced by coal.

As the rural civil construction area accounted for about 60% of the total area of the country, with the rapid development of the social economy, the original winter traditional heating methods, such as stoves, Kang, firewalls and other consumption of local biomass energy,is switching on a large scale to coal-fired boilers and disperse stoves that consume the energy of commodities , And coal as the main raw material heating mode of a single form, more energy consumption, heavy pollution, poor effect, to the atmospheric environment caused serious losses. And coal as the main raw material heating way, a single form, more energy consumption, heavy pollution, poor effect,resulting in serious damage to the atmosphere environment.

For some independent residential buildings used in gas heating wall-mounted furnace, has become a more commonly used in civil construction heating methods.Gas emissions have air pollution problems;General wall-mounted stoves are placed in small space in the kitchen or balcony, close to the living room, due to the use of conditions and product quality reasons, there are hidden dangers;It is a long-term operation of equipment, its overhaul and maintenance of the tenants themselves are not competent;Low-temperature combustion is also required for long-term uninhabited winters.

3.2 Analysis of electric heating technology

At present, the domestic electric heating technology is mainly divided into resistance and heat pump type, all kinds of electric heating technology as shown in Figure 1. In the choice of application technology of electric heating, we should aim at different types of heating objects, choose their corresponding electric heating technology, give full play to the application advantages of electric heating, realize the maximum benefit of electric heating application. The advantages and disadvantages of different heating methods are shown in table 1.

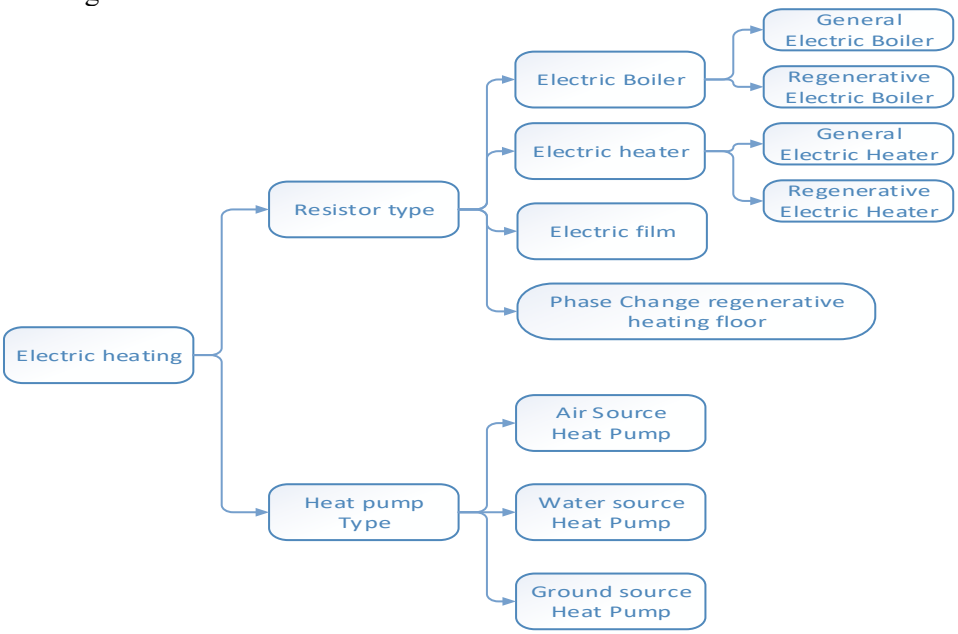

Fig1.Electric Heating Technology

Table 1 Advantages and disadvantages of different heating methods

Basic type	Specific types	Advantages	Disadvantages

Fuel heating	Coal	High operating efficiency, low cost and low operating cost	Cause serious pollution to the atmosphere
	Gas	Flexible adjustment, energy saving	Higher operating costs than coal
Electric heating	Electric Boiler	Easy automatic monitoring, simple equipment, high operating efficiency	Higher operating costs than coal
	Electric heater	Easy to buy, install and use, fast heating, flexible regulation, safe and reliable	High operating cost, low primary energy utilization in non-cogeneration power grid
	Electric film	Able to work in high temperature environment, comfortable and safe, water-saving	High operating cost, low primary energy utilization in non-cogeneration power grid
Energy storage heating	Water Regenerative Electric Boiler	Using the trough power;Low cost of energy saving equipment for traditional electric boilers	A large footprint;Need to be warmed during the day
	Solid regenerative Electric Boiler	Using the trough power，Smaller energy-saving areaCompared with the traditional electric boiler ,not only can supply heat water, but hot air	High cost of equipment purchase
Heat pump Heating	Air Source Heat Pump Water	High heating efficiency	The heating efficiency decreases with the decrease of outdoor temperature and is not suitable for cold or frost-prone areas.
	Water source Heat Pump	good heat transfer performance	Restricted by water sources
	Ground source Heat Pump	The use of renewable energy resources, economic, efficient, conservation, environmental benefits significantly	High cost of one-time investment and operation , bring geological environment problems

4.Economic benefit analysis of electric heating

4.1 Economic index analysis of electric heating

(i) Initial investment costs

1）Land use fee(remember as I1)

The main land of the heating system is the land needed for building the heat source boiler room, and the floor area of the boiler room with different heating modes is shown in table 2. Buildings for residential heating are civil,The land requisition cost of civil architecture in north China is 3 million yuan/acre (4,500 Yuan /m2).

Table 2. Estimating the floor area of various boiler houses (M2/MW)

Heat source Form	Unit heat Load Footprint
Coal-fired Boiler room	150
Gas Boiler Room	85
Heat Pump Room	65
General Electric Boiler Room	50
Water Regenerative Electric Boiler	60
Solid regenerative Electric Boiler	30

Note: According to the boiler Room design code GB50041-2008

2) Civil construction cost(remember as I2)

Civil engineering cost is construction cost to build boiler room, heat pump system including building material cost, construction labor cost and mechanical equipment use expense.The civil construction cost of a certain area in north China is 2000 Yuan /m2 from the following table 3.

Table3.Cost estimate of civil construction in different regions

Area	Civil construction cost （yuan/m^2）
North	2000
East	2100
South	2200
Central	1700
Northwest	1300
Southwest	1600
Northeast	1500

3) Equipment cost(remember as I3)

The equipment fee is the whole set price of boiler and auxiliary machine, the cost of equipment includes the purchase cost of the main body of boiler and heat pump, and the cost of purchasing the auxiliary equipment such as circulating water pump, fan and installation project cost.

4) Indoor and outdoor pipe network fee(remember as I4)

Heating system pipe Network mainly includes outdoor and indoor pipe network.The pipe net material should be selected according to the building type and construction area.

5) Total cost of initial investment(remember as I5)

The total cost of initial investment is the sum of the above several expenses, as shown in the formula (1)

$$\text{Initialinvestmentcost}=I_1+I_2+I_3+I_4+I_5 \quad (1)$$

(ii) Operating costs

The cost of heating operation mainly includes fuel cost, water and electricity cost, labor cost, operation maintenance cost and so on.

1) Fuel costs(remember as O1)

Fuel costs as the most important part of operating costs, calculated as shown in formula (2)

$$O_1=B\times P \quad (2)$$

B -Energy consumption of heating，kg；P-Fuel price，yuan.

The heating energy consumption is determined by heating consumption, and the calculation formula is as follows.

$$B=\frac{\sum Q}{Q_{dw}^{y}\times\eta_y\times\eta_w} \quad (3)$$

$$\sum Q=Q_n\times\left(\frac{t_n-t_{pj}}{t_n-t_w}\right)\times n\times 24\times 3600 \quad (4)$$

B -Energy consumption of heating，kg；$\sum Q$ - Total heat consumption of Heating season，KJ；Q_{dw}^{y}-Calorific value of fuel unit，KJ/Unit；η_y，η_w-Heat source、Heat efficiency of pipe network；Q_n —thermal load of heating，KW；t_n —Indoor calculation temperature in heating period，$^{\circ}C$,Usually take 18 ℃；t_{pj} —Outdoor average temperature during heating period，$^{\circ}C$；t_w-

Outdoor calculation temperature of heating period, $^{\circ}C$; n-Days of heating period, days, $\varphi = \frac{t_n - t_{pj}}{t_n - t_w}$, Average coefficient of thermal load.

The low calorific value and fuel price of various common fuels are shown in table 4, and the operating costs of each of the four heating schemes can be calculated separately according to the data in the table.

Table 4. Fuel low calorific value and price for different heating schemes

Fuel Type	Calorific value of fuel	Fuel price	Unit calorific value
Coal	29.27MJ/kgce	770yuan/t	0.0263yuan/MJ
II bituminous Coal	17.61MJ/kg	468yuan/t	0.0266yuan/MJ
Electric	3.6MJ/kWh	0.5yuan/kWh	0.1389yuan/MJ
Gas	35.58MJ/m^3	2.67yuan/m^3	0.1265yuan/MJ

Note: The fuel calorific value of this table is based on China Coal Classification National Standard (GB5751-86).

2) utilities(remember as O2)

Water charges are the total cost of the amount of water injected into the system of the boiler heating sysyem and the additional water,The calculation formula is as follows.

$$O_2 = Q \times P \tag{5}$$

Q-Quality；P-Price,yuan.

3) labor costs(remember as O3)

The labor cost is to pay the workers ' wages during the heating system operation. After inquiry data, the average wage in north China is 160 yuan/day.

$$O_3 = N \times \phi \times n \tag{6}$$

Φ-Average wage,yuan；n-Days of labouring period，days。

4) Other costs(remember as O4)

Other expenses mainly include the equipment maintenance cost during the operation of heating equipment generally charged based on the construction area or the usage area.

5) Operation Total Cost

The sum of the costs of the operation, as shown in the formula (7)

$$\text{Operating costs} = O_1 + O_2 + O_3 + O_4 \tag{7}$$

(iii) Comparison method of cost year value

The cost year value is the cost of the initial investment by the equipment life cycle depreciation to each year, and then the annual operating costs added，we can compare the economic benefits of different life cycle projects by calculating the annual value AW of project cost, and calculate the formula as follows

$$AW = C_0 \times (A/P, i, n) + C$$
$$(A/P, i, n) = \frac{i \times (1+i)^n}{(1+i)^n - 1} \tag{8}$$

Among them, i for the investment rate of return, take 10%; n for life period, C0 for the initial investment cost, C for the annual operating costs.

4.2 Empirical study on residential electric heating

(i) Architectural overview

Taking the Highland Garden community of Yanbian as an example, the current winter heating mode of Highland Garden District is for the water storage and thermoelectric boiler heating, Building type and

construction area: Civil construction;Total building area is 110177m2;The actual heating area is 92687m2,the number of households is 1166 households.

At present,Highland Garden Heating mode is water regenerative type, the heating mode can also be coal, gas and electric heating, selected for electric heating technology mainly are ground-source heat pump and ordinary electric boilers, solid storage and thermoelectric boilers.

(ii) Comparison of initial investment costs

Through the calculation above, we can sum up the initial investment cost comparison of different heating modes in the Highland Garden District of Yanbian area, as shown in table 5 below.

Table 5.Comparison of initial investment in unit heating area with different heating modes

Compare items	Coal-fired Boiler room	Gas Boiler Room	Ground source Heat Pump	General Electric Boiler	Water Regenerative Electric Boiler	Solid regenerative Electric Boiler
Land use fee	60.02	34.01	26.01	20.01	24.01	12
Civil cost	90.02	51.01	39.01	30.01	36.01	18
Equipment cost	210	290	1000	540	620	610
Pipe network Cost	342.9	342.9	342.9	342.9	342.9	432.9
Initial investment costs	702.94	717.92	1407.92	932.92	1022.92	982.90
Overall cost of equipment	15	15	25	25	25	25
Cost year value	262.9	447.32	302.02	736.39	529.67	443.12

By comparing the initial investment cost of different heating modes, it can be found that the ground-source heat pump heating system should be significantly higher than other heating modes in the initial investment.Electric boiler heating and coal, gas heating initial investment expenses are similar.Although the initial investment cost of the electric heating method is higher than the that of the coal-fired gas boiler, however, combined with the heating energy consumption and pollutant emission, the comprehensive benefit of the electric heating mode is higher than the ordinary heating mode.

(iii)Economic benefit analysis of operation cost

The total heat load of the building is 4001KW，To calculate the total heat load of the heating season，the heating period is 183 days and the heating time is 24h each day. The average value of the heat load is as follows.

$$\varphi = \frac{t_n - t_{pj}}{t_n - t_w} = 0.635 \quad (9)$$

The heating season heat load of the project is calculated according to the formula (4):

Highland Garden Total Construction area is 110177m2, the actual heating area is 92687m2, the heating design heat load is 4001KW;

$\sum Q = 4001\text{KW} \times 0.635 \times 183 \times 24\text{h} = 113.9 \times 10^5\text{kWh}$，1kWh=3600J

According to the above calculation,the details of the operation of different heating modes in Highland Garden District are shown in table 6 below.

The operating costs of different heating modes are shown in table 7 below.

Table6. Operation of different heating modes

	Operational efficiency	Fuel	Fuel prices	Energy consumption
Coal	0.7	II bituminous Coal	468yuan/t	3259.19
Gas	0.9	Gas	2.67yuan/m3	$1254.64*10^3m^3$
Ground source Heat Pump		electric	0.5250/kWh	$25.36*10^5$kWh
Electric Boiler	0.98	electric	0.5424/kWh	$113.9*10^5$kWh
Water Regenerative			Peak 0.78285/kWh	

Electric Boiler	0.98	electric	Trough 0.5324/kWh	$81.97*10^5$
			Flat 0.28195/kWh	$31.93*10^5$
Solid regenerative Electric Boiler	0.98	electric	Trough 0.28195/kWh	$113.9*10^5$

Table7. Comparison of operating cost of different heating modes

	Energy consumption	Power consumption(kWh)	Operating costs(yuan)	Operating cost per unit area（元）
Coal boiler room	3259.19t II bituminous Coal	35000	1704800	15.47
Gas boiler room	$1254.64\times103m^3$ Gas	35000	3529400	32.03
Ground source heat pump system		2536000	1469100	13.33
General Electric Boiler		11390000	6336100	57.51
Water Regenerative Electric Boiler		11390000	4169700	37.85
Solid regenerative Electric Boiler		11390000	3348300	30.39

By comparing the annual operating cost of heating mode, It can be found that the operating cost of the ground source heat pump system is the lowest, and the heating system of the ordinary electric boiler is higher than other heating modes, and the annual operating cost of the water storage and the solid heat storage boiler is obviously improved, which is less than the running cost of the gas-fired boiler house, and has good economy.

(iv)Annual Revenue Analysis

The sales revenue of heating enterprises mainly refers to the heating income,The heating price of Yanbian city is about 31 yuan /m^2 by residential heating area,The heating revenue is the same, the annual heating of Yanbian area is 2.8733 million yuan.

Table 8. Income comparison of different heating methods

	Annual Sales revenue（yuan）	Cost year value（yuan）	Annual revenue （万元）
Coal-fired Boiler room	2873300	262.9000	24.43
Ground source heat pump system	2873300	302.0200	-14.69
General Electric Boiler	2873300	736.3900	-449.06
Water Regenerative Electric Boiler	2873300	529.6700	-242.34
Solid regenerative Electric Boiler	2873300	443.1200	-155.79

4.3 Economic benefit evaluation by Net Present Value

Net present value method refers to the algebra and the present value of the net cash flow of each period in the economic life cycle of the project according to a specified benchmark rate of return.

The formula is as follows:

$$NPV = P_0 + \sum_{t=1}^{n} \frac{F_t}{(1+i)^t} + A\left[\frac{(1+i)^n - 1}{i(1+i)^n}\right] \quad (10)$$

In the formula:

NPV--Net present value；

P0--Cash flow for the No. 0 year;

Ft--Non-uniform cash flow for T-year;

N--Uniform cash flow from 1th year to nth year

NET residual value is usually calculated by 3%-5% of the original value of the fixed asset,Here we define the net residual value 5% of the fixed asset;Predetermined benchmark rate of return,i0=15%.

The results obtained from Table 9 below are:$N_{pump}>N_{Solid}>N_{Water}>N_{Electric\ Boiler}$. For Highland Garden community,the ground source heat pump has the best heating mode.

Table 9. Specific conditions of different heating modes

	coal	Ground source heat pump system	General Electric Boiler	Water Regenerative Electric Boiler	Solid regenerative Electric Boiler
Initial investment costs	702.94	1407.92	932.92	1022.92	982.90
Annual income	24.43	-14.69	-449.06	-242.34	-155.79
Residual value	35.147	70.396	46.646	51.146	49.145
Service Period	15	25	25	25	25
NPV	-555.72	-1502.49	-3832.45	-2586.88	-1987.20

4.4 Government subsidy policy

In order to solve the problem of high initial investment of electric heating users, it Can be considered that the government implement electricity heating subsidies to help users, providing users with a part of the funds for the purchase of electric heating equipment and electric heating construction.

Take Highland Garden as an example, from the calculation above can be obtained, both coal-fired heating investment cost and operating cost is low, making ithe initial investment cost of coal-fired heating and electricity price as the standard price, the government can subsidize from two aspects:

(i) Tariff subsidy

To ensure that the initial investment costs of heating methods,The details of the government's subsidy to the electricity price are shown in Table 13 below.

From the Highland Garden in 2017, the total electricity was 113.9x105kwh; For the water regenerative heating method, of which about 71.97% of the power in the valley, about 81.97x105kwh, flat section of electricity accounted for 28.03%, about 31.93x105kwh. The Government should therefore subsidize the subsidies.

It can be obtained from table 10 below that the General Electric boiler without peak and valley electricity price has the highest price to subsidize, so making the subsidized electricity price is I.

$$I_{\text{Electric Boil}}>I_{Water}>I_{Solid}>I_{\text{pump}}$$

Table10 .Government fuel price subsidies

	Fuel price/yuan/kWh	Operating costs after reform/yuan	Government subsidized fuel prices yuan/kWh
Coal	468yuan/t		
Ground source Heat Pump	0.5250	1221800	0.097
General Electric Boiler(No peak-Valley electricity price is used)	0.5424	1696700	0.390
General Electric Boiler（Use peak and valley electricity price)	Peak 0.78285	1597400	0.156
	Flat 0.5324		
	Trough 0.28195		
Water Regenerative Electric Boiler	Peak 0.78285	1540700	0.170
	Flat 0.5324		
	Trough 0.28195		
Solid regenerative Electric Boiler	Trough 0.28195	1546100	0.148

(ii)Initial investment and tariff subsidy

Given the initial investment cost of different electric heating methods, the government should give full support to the initial investment cost of different electric heating methods.Namely the investment ground source heat pump 14.0792 million yuan, the General Electric boiler 9.3292 million yuan, the water regenerative electric boiler 10.2292 million yuan, as well as the solid regenerative electric boiler

9.829 million yuan. After the initial investment subsidy, the electricity price subsidy is given to different electric heating modes, as shown in table 11 below.

The following table shows that the government's tariff subsidy policy for different heating modes

$$I_{\text{Electric Boil}} > I_{\text{Water}} > I_{\text{Solid}} > I_{\text{pump}}$$

In most areas of our country, the peak and valley electricity price has been adopted for heating electric boilers, and through the above calculation we can also get the electric boiler heating with very good economic benefit after using the peak-Valley electricity price policy.

Table 11. Government initial investment and tariff subsidy (unit: million)

	Initial investment costs	Cost year value	Initial investment cost of government subsidy	Government subsidy electricity price yuan/kwh
Ground source Heat Pump	1407.92	302.02	1407.92	0
General Electric Boiler(No peak-Valley electricity price is used)	932.92	736.39	932.92	0.334
General Electric Boiler（Use peak and valley electricity price)	932.92	525.44	932.92	0.089
Water Regenerative Electric Boiler	1022.92	529.67	1022.92	0.134
Solid regenerative Electric Boiler	982.90	443.12	982.90	0.101

5.Conclusions

In order to make the public better understand the advantages of electric heating, accept and adopt this new type of heating, this paper analyzes the technical scheme of electric heating.From the angle of economic benefit, this paper makes a deep comparative study on the heating methods of electric heating, such as coal and gas, and draws the following conclusions:

1）This paper classifies the main electric heating technology in China, it is mainly divided into resistance type and heat pump type, the advantages and disadvantages of various electric heating technology are introduced.At the same time, it should be noted that in the selection of application technology of electric heating, we should choose the suitable electric heating technology for different types of heating objects to realize the maximum benefit of electric heating application.

2）The use of electric heating to replace the need to invest a part of the funds for electric heating reform, in order to solve the problem of high investment costs, to stimulate the user to replace the enthusiasm of electric heating, it can be considered by the government to carry out electric heating replacement of the user electric heating reform subsidy, The government can carry out from two aspects, one of which is to provide subsidy for initial investment, and the other is to subsidize the electricity price on the basis of providing initial investment subsidy.

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